A CENTRALIZED LOCALIZATION ALGORITHM FOR PROLONGING THE LIFETIME OF WIRELESS SENSOR NETWORKS USING PARTICLE SWARM OPTIMIZATION IN THE EXISTENCE OF OBSTACLES

ALI HUSAM ABDULHASAN AL-JARAH

A thesis submitted in partial
fulfilment of the requirements for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2017

Dedicated to,

My beloved father and mother,

Husam Abdulhasan and Nadia Shakir

My brother,

Ahmed Husam,

My sisters,

Zahra and Benien,

My friends and colleagues

My supervisor PROF. MADYA DR. JIWA BIN ABDULLAH.

ACKNOWLEDGMENT

Foremost, all praises to Almighty ALLAH, Whose give me strength and perseverance to make me able to complete this master degree, without ALLAH I cannot do anything in this life. Therefore he is the only one I have to be thankful for him from heart.

I would like to express the deepest gratitude to my honorable supervisor. Prof. Madya Dr. Jiwa bin Abdullah for his kind support, valuable ideas, assistance, guidance and encouragement throughout this thesis.

Also, my gratitude to the cooperation given by Faculty of Electrical and Electronics Engineering (FKEE) in University Tun Hussein Onn Malaysia (UTHM).

My greatest appreciation goes to all my friends and colleagues who always helped and motivated me during my master degree and through this project.

Last but not least, with all of my love, I would like to express my honest thanks to all my family members for their love, encouragement, prayers and motivations a long all years of my life. I am deeply and forever indebted to my parents, both financially and emotionally throughout my entire study. Without them I could not have made my study. I would like to truthfully acknowledge the sincere help and the moral support of all those inspired me to complete my study.

ABSTRACT

The evolution in micro-electro-mechanical systems technology (MEMS) has triggered the need for the development of wireless sensor network (WSN). These wireless sensor nodes has been used in many applications at many areas. One of the main issues in WSN is the energy availability, which is always a constraint. In a previous research, a relocating algorithm for mobile sensor network had been introduced and the goal was to save energy and prolong the lifetime of the sensor networks using Particle Swarm Optimization (PSO) where both of sensing radius and travelled distance had been optimized in order to save energy in long-term and short-term. Yet, the previous research did not take into account obstacles' existence in the field and this will cause the sensor nodes to consume more power if obstacles are exists in the sensing field. In this project, the same centralized relocating algorithm from the previous research has been used where 15 mobile sensors deployed randomly in a field of 100 meter by 100 meter where these sensors has been deployed one time in a field that obstacles does not exist (case 1) and another time in a field that obstacles existence has been taken into account (case 2), in which these obstacles has been pre-defined positions, where these two cases applied into two different algorithms, which are the original algorithm of a previous research and the modified algorithm of this thesis. Particle Swarm Optimization has been used in the proposed algorithm to minimize the fitness function. Voronoi diagram has also used in order to ensure that the mobile sensors cover the whole sensing field. In this project, the objectives will be mainly focus on the travelling distance, which is the mobility module, of the mobile sensors in the network because the distance that the sensor node travels, will consume too much power from this node and this will lead to shortening the lifetime of the sensor network. So, the travelling distance, power consumption and lifetime of the network will be calculated in both cases for original algorithm and modified algorithm, which is a modified deployment algorithm, and compared between them. Moreover, the maximum sensing range is calculated, which is 30 meter, by using the binary sensing model even though the sensing module does not consume too much power compared to the mobility module. Finally, the comparison of the results in the original method will show that this algorithm is not suitable for an environment where obstacle exist because sensors will consume too much power compared to the sensors that deployed in environment that free of obstacles. While the results of the modified algorithm of this research will be more suitable for both environments, that is environment where obstacles are not exist and environment where obstacles are exist, because sensors in this algorithm .will consume almost the same amount of power at both of these environments.

ABSTRAK

Evolusi dalam teknologi sistem mikro elektrik-mekanik (MEMS) telah mencetuskan keperluan terhadap pembangunan dalam rangkaian pengesan tanpa wayar (WSN). Nod pengesan tanpa wayar telah banyak digunakan dalam aplikasi pelbagai bidang. Salah satu isu penting dalam WSN ialah ketersediaan tenaga yang selalu menjadi kekangan. Dalam penyelidikan terdahulu, pindahan semula algoritma untuk rangkaian pengesan mudah alih telah diperkenalkan dan matlamatnya ialah untuk menjimatkan tenaga dan memanjangkan jangkahayat pengesan rangkaian dengan menggunakan Pengoptimuman Gerombolan Zarah (PSO) di mana kedua-dua jarak pengesanan dan jarak ditempuhi telah dioptimumkan bertujuan untuk menjimatkan tenaga dalam jangka panjang dan jangka pendek. Namun penyelidikan sebelumnya tidak mengambil kira halangan yang wujud dalam lapangan dan ini akan menyebabkan nod pengesan menggunakan lebih kuasa jika halangan wujud dalam lapangan pengesanan. Dalam projek ini, algoritma relokasi terpusat yang sama dari penyelidikan terdahulu telah digunakan di mana 15 sensor mudah alih digunakan secara rawak dalam bidang 100 x 100 meter di mana sensor ini telah digunakan satu kali dalam bidang bahawa halangan tidak wujud (case 1) Dan satu lagi masa dalam bidang bahawa kewujudan halangan telah diambil kira (kes 2), di mana halangan-halangan ini telah ditentukan sebelumnya, di mana kedua-dua kes ini digunakan dalam dua algoritma yang berbeza, iaitu algoritma asal penyelidikan terdahulu Dan algoritma yang diubahsuai dalam tesis ini. Pengoptimuman Swarm Partikel telah digunakan dalam algoritma yang dicadangkan untuk meminimumkan fungsi kecergasan. Rajah Voronoi juga telah digunakan untuk memastikan bahawa sensor mudah alih meliputi seluruh bidang penderiaan. Dalam projek ini, matlamat akan menjadi fokus utama pada jarak perjalanan, iaitu modul mobiliti, sensor mudah alih dalam rangkaian kerana jarak yang nod sensor bergerak, akan menggunakan terlalu banyak kuasa dari nod ini dan ini akan membawa kepada Memendekkan jangka

hayat rangkaian sensor. Oleh itu, jarak perjalanan, penggunaan kuasa dan hayat rangkaian akan dikira dalam kedua-dua kes untuk algoritma asal dan algoritma yang diubahsuai, iaitu algoritma penggunaan yang diubah suai, dan membandingkan di antara mereka. Selain itu, julat penderiaan maksimum dikira, iaitu 30 meter, dengan menggunakan model penginderaan binari walaupun modul pengesan tidak menggunakan terlalu banyak kuasa berbanding dengan modul mobiliti. Akhirnya, perbandingan hasil dalam kaedah asal akan menunjukkan bahawa algoritma ini tidak sesuai untuk persekitaran di mana penghalang wujud kerana sensor akan menggunakan kuasa terlalu banyak berbanding dengan sensor yang digunakan dalam persekitaran yang bebas daripada halangan. Walaupun hasil algoritma yang diubah suai bagi penyelidikan ini akan lebih sesuai untuk kedua-dua persekitaran, iaitu persekitaran di mana rintangan tidak wujud dan persekitaran di mana rintangan wujud, kerana sensor dalam algoritma ini akan memakan hampir jumlah kuasa yang sama pada kedua-dua Persekitaran ini.

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INTRODUCTION

1.1 Research Background

Wireless sensor network is a network system that formed by a number of sensor nodes working together for gathering information from the surroundings of an environment and then transmitting the data to a base station in order to process the received information (X. Zhang, 2012). After collecting the information from the environment and sending them to the base station, which provides a connection to the wired world, the collected data is processed, analyzed and presented into useful applications as shown in Figure 1.1.

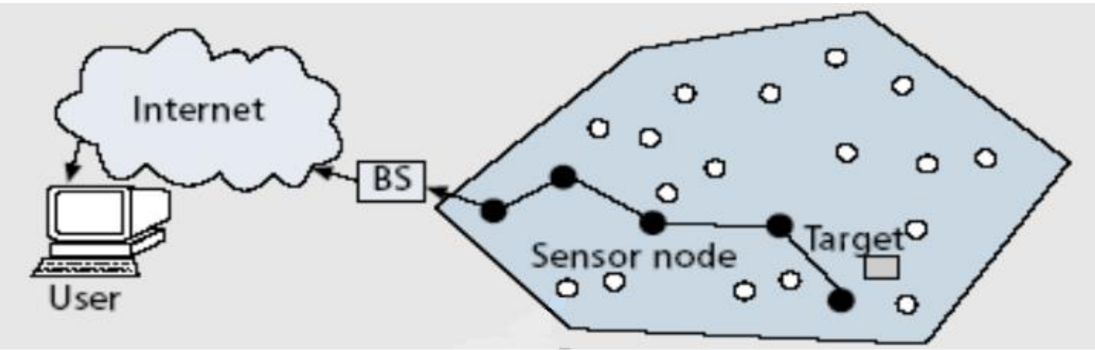

Figure 1.1: Wireless Sensor Network General Function
(GUPTA & SINHA, 2014)

The sensor node is a distinct small device that usually consists of four main units which are sensing, processing, communication and power supply (GUPTA & SINHA, 2014). Wireless sensor network (WSN) may be deployed using hundreds or thousands of these tiny sensor nodes in order to monitor a certain physical phenomena or to detect and track a certain objects in the area of interest. These WSNs have gained worldwide attention in recent years specially with the increasing in micro-electro-mechanical systems (MEMS) technology, wireless communications and digital electronics that enabled the development of a low-cost, low-power, multifunctional and smart sensor nodes which are small in size and communicate untethered in short distances (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002).

Smart sensor nodes are low power devices which equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator. Different types of sensors, which are mechanical, thermal, biological, chemical, optical, and magnetic, might be attached to the sensor node for measuring the properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is implemented for wireless communication to transfer data to a base station (e.g., a laptop, a personal handheld device, or an access point to a fixed infrastructure). Battery is the main power source in a sensor node. Secondary power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed. Depending on the application and the type of sensors used, actuators may be incorporated in the sensors (Yick, Mukherjee, & Ghosal, 2008).

Wireless sensor networks offer new applications in the areas of habitat and environment monitoring, disaster control and operation, military and intelligence control, object tracking, video surveillance, traffic control, as well as in health care and home automation. Moreover, the integration of multiple types of sensors such as seismic, acoustic, optical, etc. in one network platform and the study of the overall coverage of the system also presents several interesting challenges and one of these challenges is power efficiency (García-hernández, Ibargüengoytia-gonzález, García-hernández, & Pérez-díaz, 2007). It is likely that the deployed sensors will be batterypowered, which will limit the energy capacity significantly. Thus, energy efficiency becomes one of the main challenges that need to be taken into account. For this project, the application used in wireless sensor networks will be for measuring humidity. Since the major contribution of this research is saving the power of the sensor nodes and prolong the lifetime of the sensor network in term of mobility, it will be better to assume a simple application measurement, which is humidity, so that sensing, communication and computation mode will not consume too much power.

1.2 Problem Statement

The advances in Micro-Electro-Mechanical Systems, digital electronic and wireless communication have led to emergence of wireless sensor networks (WSNs), which consist of a large number of sensing devices each capable of sensing, processing and transmitting environmental information. A single sensor node may only be equipped with limited computation and communication capabilities. However, these approaches are not energy efficient (*Guide to Wireless Sensor Networks - Google Books*, n.d.).

It has been widely argued that the transmission and reception energy per bit is much larger than sensing and processing energy per bit. So, energy availability has always been a constraint in WSN because the power supply of a single sensor node relies on battery of limited energy in general. Recharging the nodes' battery is very difficult after the deployment of these sensor nodes. Therefore, it is better to design energy efficient algorithms to save energy and prolong the lifetime of the sensing nodes. (Qu & Georgakopoulos, 2012) proposed a centralized relocating algorithm for mobile sensor network aiming to save energy and prolong the lifetime of sensor networks. This algorithm uses Particle Swarm Optimization (PSO) and both of the sensing radius and travelled distance are optimized to save the energy in long- and short-term.

The problem in the proposed algorithm is that it does not take into account the existence of obstacles in the sensing field, which means the nodes deployed in a free space. Therefore, in this thesis we will show the consequences of the original algorithm by applying obstacles in the sensing field. Then, try to come up with a suitable modification to the original algorithm to make it suitable for both environments, which are the free space environment and obstacle existence environment, in term of power consumption and finally compare the results of the original algorithm of (Qu & Georgakopoulos, 2012) and the modified algorithm.

1.3 Objectives

The objectives of this project are:

1. To study the power consumption technique of the sensor nodes in the original algorithm once without obstacles in the sensing field, which is assumed to be case 1, and another time in a field where obstacles are considered in the sensing field, which is assumed to be case 2.

2. Develop an algorithm to save the energy of the sensor node to be suitable for both cases, which are in free space and in obstacles existence environment, and also compare between these cases.

3. Evaluate the results of the original algorithm and the modified algorithm in term of travelling distance, power consumption and lifetime of the network for each in both cases and then compare between both of these two algorithm in term of fitness function in case 2, where obstacles exist, to check which algorithm is more suitable for this environment.

1.4 Scope of Study

By setting a sensing field with obstacles exist in it, consider that the obstacle will be in the way of the movement of the sensor node as shown in Figure 1.2. So, if the initial deployment position of a sensor exists for example in the opposite of the obstacle and the destination (final) position of that sensor exists behind that obstacle, it means that the mobile sensor can't move at line of sight from its initial position to its final position, therefore we will prepare a set of algorithms to solve this problem.

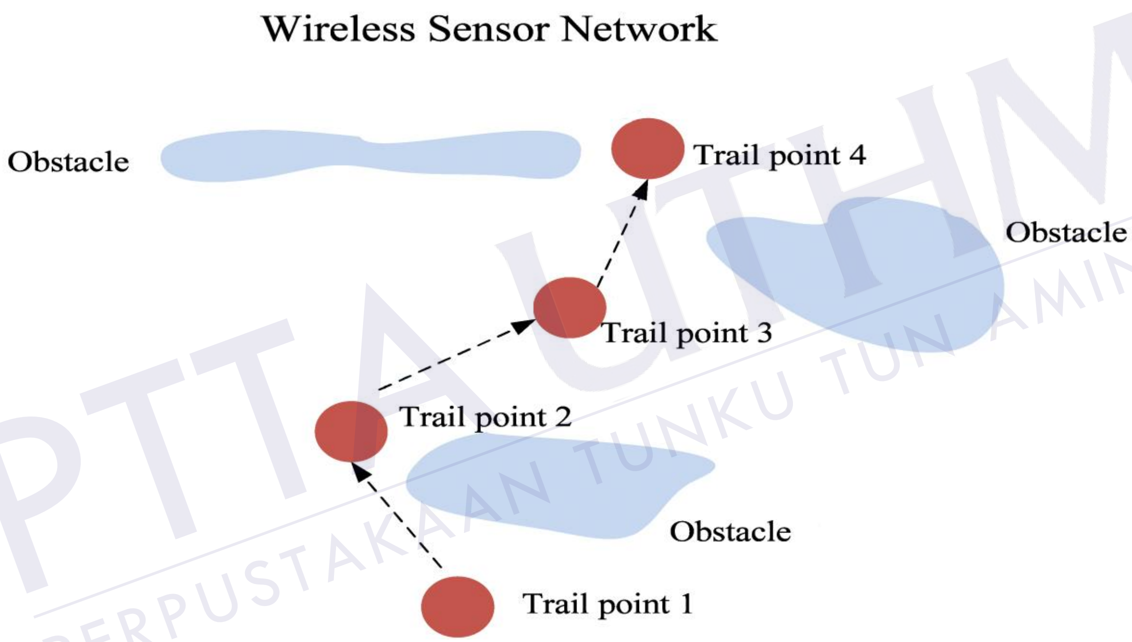

Figure 1.2: The problem of obstacles existence in the sensing field

The proposed algorithms consist of few steps by testing if there are any structures in the field where the sensor node deployed and no restriction there in the movement of the sensor node (as previously referred to it as the initial deployment point and the destination point). If there is any restriction in the sensor's movement because of the existence of obstacles, then a proper calculation of the distance between the initial deployment point and the starting point will be considered otherwise, the sensor node can move to the destination point freely and without any restrictions.

In case of the existence of obstacles in front of the sensor node, the procedure is taking the shortest route around the obstacle as in Figure 1.3. The shortest route will be determined by calculating the traveling distance from the initial position to destination position using the Euclidian equation in order to reduce energy consumption and lead to prolong the lifetime of the sensor network.

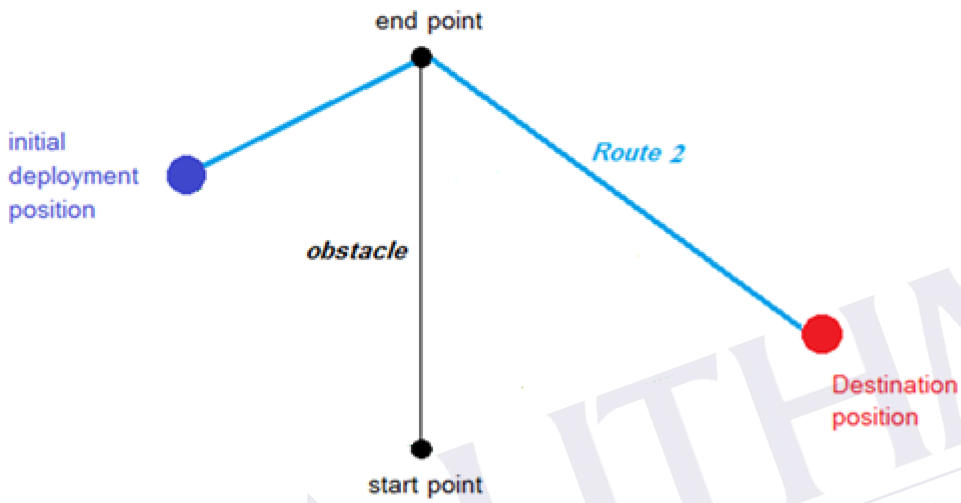

Figure 1.3: the proposed routs of the discussed problem in case of one obstacle existence

In addition to the calculation of traveling distance and power consumption, models and diagrams will be used like the sensing model, which responsible for calculation the sensing radius of each sensor and also Voronoi diagram has been used to make sure that sensors will cover the whole sensing field. Moreover, particle swarm optimization will be used in order to minimize the fitness function.

Since the aiming to reduce energy consumption and prolong the lifetime of the sensor network by optimizing both of sensing radius and travel distance, we can suppose that the travel distance of mobile sensor would not exceed a squared area from its center of the initial deployment position of that sensor with its side length is L meter. We will use the concept of this area to initialize the particles, and we expect that PSO algorithm with this modification will reach the solution faster than the original PSO algorithm due to that the particles are initialized in near positions to their final positions.

1.5 Thesis Organization

The rest of this thesis is organized as follows: Chapter 2 presents a survey about the major challenges and issues in the wireless sensor networks and an overview about the each function mode in the sensor node and their roles in power consumption with the methods from previous researches, explained briefly, for energy conservation. Also, the literature will explain the theory and types of localization and particle swarm optimization that used in previous researches. The methodology of the project, parameters and simulation tools, which are the equations, will be explained in chapter 3. The simulation results and analysis are presented in chapter 4. Finally, the project conclusion and the future works will be done in Chapter5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides insights about the major challenges and issues in wireless sensor network, energy consumption in different modes of the sensor node, energy conservation techniques that used in a previous researches, particle swarm optimization methods in WSN, and localization algorithms for understanding the lifetime extension of the sensor network.

2.2 Major Challenges and Issues in Wireless Sensor Networks

The major issues and challenges that will be reviewed briefly in wireless sensor network are for hardware of the sensor node, operating system and software programming, wireless radio communication, architecture, wireless network layers, deployment, synchronization and localization, security, and energy.

2.2.1 Hardware of the Sensor Node in WSNs

As explained before, the mobile sensors are tiny devices that use for sensing, processing and transmitting the sensed data from the physical environment that used in many applications and these sensors called nodes. A sensor node consists of processor, memory, battery, A/D converter for connecting to a sensor and a radio transmitter for forming an ad hoc network (Vieira, Coelho, Da Silva, & Da Mata, 2003). The structure of the sensor node is as shown in Figure 2.1.

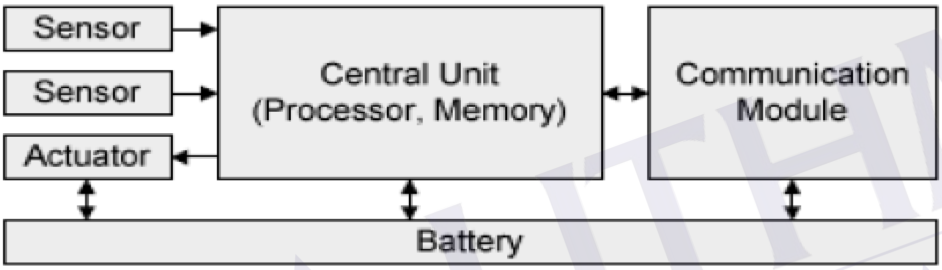

Figure 2.1: Structure of Sensor Node
(Bansal, 2015)

The hardware design issues in the these sensor nodes are (P. Zhang, Sadler, Lyon, & Martonosi, 2004):

1. Radio Range of nodes should be high (1-5 kilometers). Radio range is crucial for ensuring network connectivity and data gathering in a network as the environment being examined may not have an installed infrastructure for communication.
2. Sensor Networks consists of hundreds of thousands of nodes. It is preferred only if the node is cheap like using a flash memory as a chip of memory because it is reprogramed, inexpensive and non-volatile.
3. The central processing unit of sensor node determines energy consumption and computational capabilities of a node.

In the research area, there are different methods to deal with the hardware issues in order to improve signal reception, design of low power, less cost sensors and processing units. One of these researches is for saving of power of microcontroller by designing it in three states, which are active, sleep and idle. Also, various schemes to conserve node power consumption and node optimization and simple modulation schemes may also be considered for sensor nodes.

2.2.2 Operating System and Software Programming

Operating System architecture for the sensor nodes is usually separated (independent) from the hardware of these nodes. It plays an important role in solving many important design issues regarding memory management and resource management. Generally, the operating system (OS) should be less complex than the general operating systems and must have an easy programming model due to power, processing and storage constraints that require power efficiency (Eswaran, Rowe, & Rajkumar, 2005), reactivity, mobility, fault tolerance, and concurrency. There are various operating systems developed for sensor nodes and the most known types of these operating systems are: Mantis-OS (Abrach et al., 2003), Nano-Qplus (Abrach et al., 2003) and Tiny-OS (Levis et al., 2004), which is implemented in NesC language (Gay et al., 2003).

On the other hand, programmers deal with too many low levels details regarding sensing and communication of software programming in the sensor nodes. For example, they typically deal with particular node to node communication and deal with sensing, fusing and moving data and also. Researches in programming abstractions for WSN can be categorized into 7 areas: environmental, middleware APIs, database centric, event based, virtual machines, script and component-based. As an example, consider an environmental based abstraction called Enviro-Track (Abdelzaher et al., 2004).

Application developers should be able to concentrate on their application logic instead of being concerned with the low level hardware issues like scheduling, preempting and networking.

2.2.3 Wireless Radio Communication

Performance of wireless sensor networks depends on the quality of wireless communication yet wireless communication in sensor networks is known for its unpredictable nature. The main issues of the wireless communication in WSN are (Vieiral et al., 2003):

1. Facilitating low duty cycle operation, local signal processing, to in order to lower the consumption of the power.
2. Distributed sensing effectively towards various environmental obstacles and this will affect the strength of the signal and the effective radio range.
3. Multi-hop networking may be adapted among sensor nodes to reduce communication link range and also density of sensor nodes should be high.
4. Long range communication is typically point to point and requires high transmission power, with the danger of being eavesdropped.
5. Errors during the wireless communications.

Research areas include designing low power consuming communication systems and complementary metal oxide semiconductor (CMOS) circuit technique specifically optimized for sensor networks, designing new architecture for integrated wireless sensor systems and modulation method and data rate selection.

2.2.4 Architecture

Architecture can be considered as a set of rules and regulation for implementing some functionality along with a set of interfaces, functional components, protocols and physical hardware (Jangra, 2010). Lack of overall sensor network architecture is limiting the progress in this field. Software architecture is needed to bridge the gap between a hardware capabilities and a complete system. Sensor network architecture should be durable and scalable in order to allow changes in topology with minimum

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